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(54) **A high temperature furnace with anisotropic thermal insulation**

(57) A furnace comprising a heater (2) installed around a muffle tube (1), with insulation (4) arranged around the heater. The insulation comprises six parts (4a to 4f) arranged such that it exhibits anisotropy in heat transfer and the direction along which the thermal conductivity of the insulation is small corresponds to the direction along which the temperature gradient within the insulation is steep.

Fig. 3

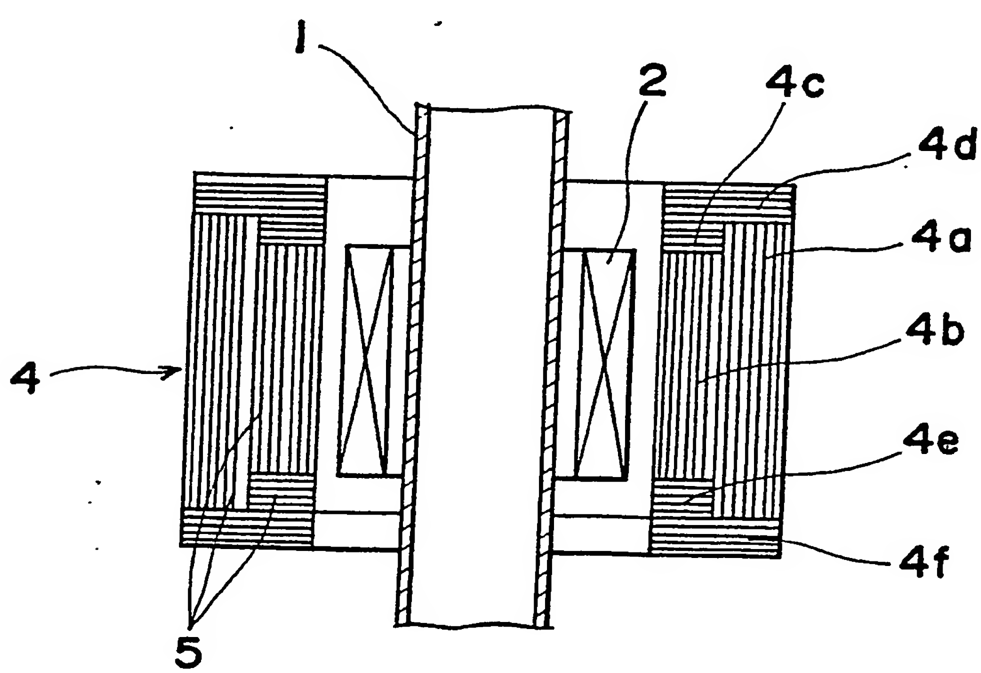

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Fig. 1 Prior Art

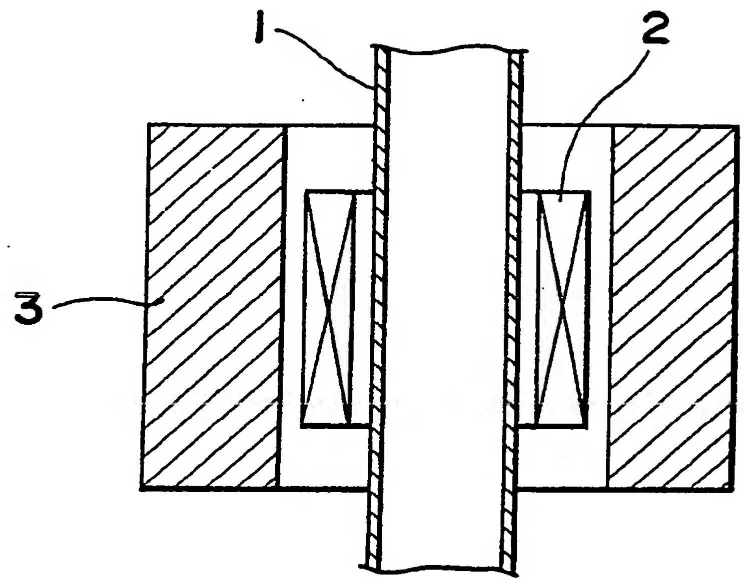

Fig. 2 . Prior Art

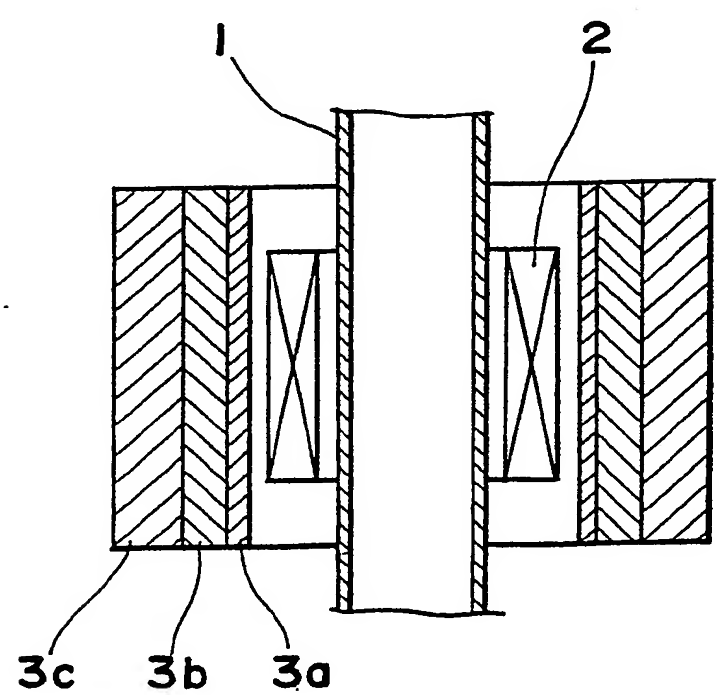

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Fig. 3

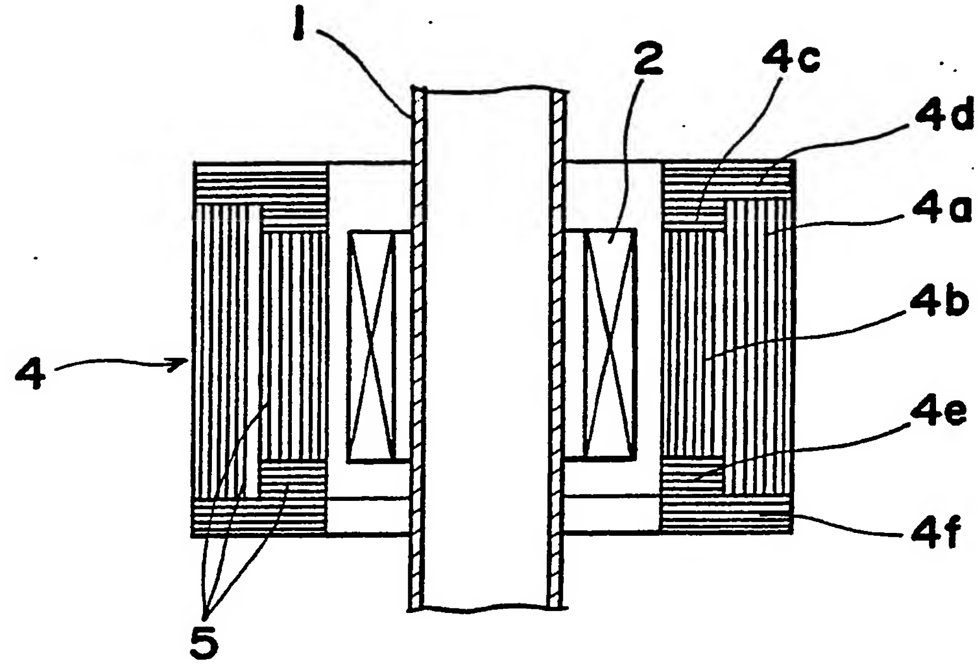

Fig. 4

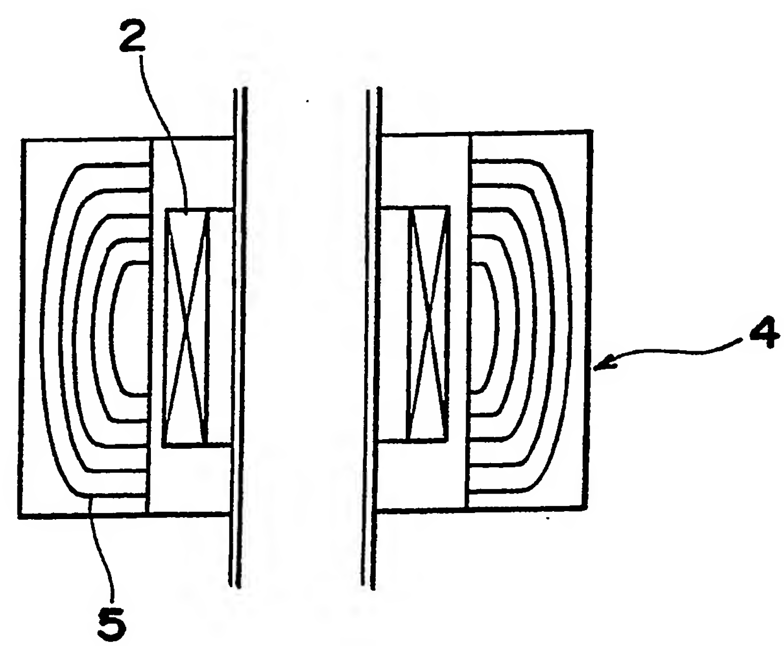

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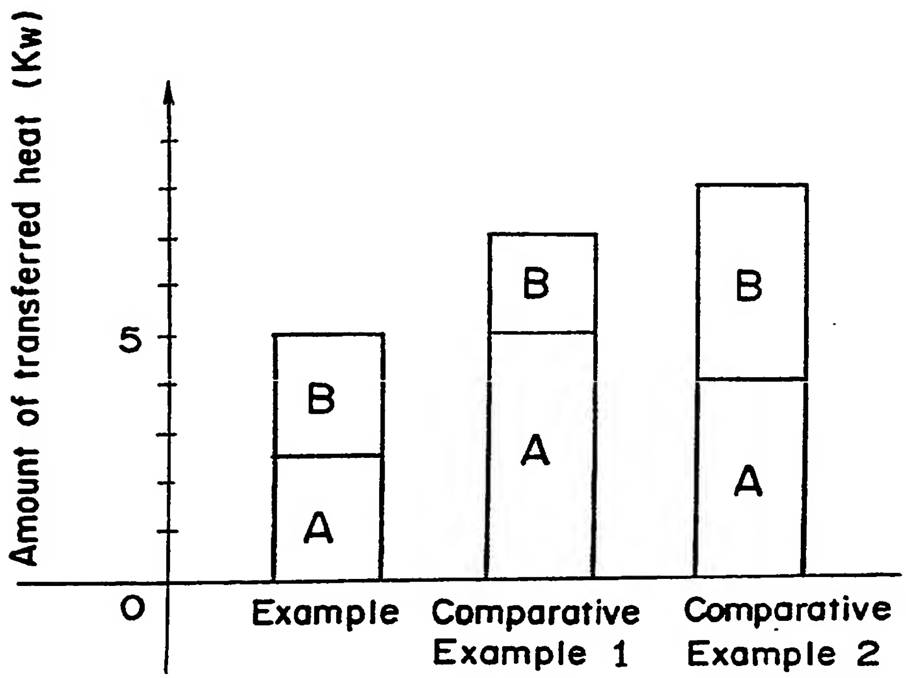
Fig. 5



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"A HIGH TEMPERATURE FURNACE WITH THERMAL INSULATION"

The present invention relates to the thermal insulation of a furnace such as an optical fibre drawing furnace, a sintering furnace for a glass preform for an optical fibre and a semiconductor pulling-up furnace and the like, particularly those used at a high temperature, for example higher than 1000 °C. Hereinafter, such the furnace is generally referred to as a high temperature furnace.

When a high temperature furnace is thermally insulated in order to reduce heat loss, usually a carbon felt, a ceramic fibre felt or similar material is used for the insulation of the furnace. In order to prevent the fibres in the felt from scattering, the insulation is contained in a cylindrical container, or shaped into a cylindrical form of moulded felt.

When such the shaped felt is used as the insulation in the furnace, as shown in Figure 1 of the accompanying drawings, the shaped felt is located around a heater 2 which is installed around a muffle tube 1. With the use of the shaped felt as described above, the heat loss through a container containing the felt can be advantageously eliminated since the container can be omitted. It may also be possible to coat the shaped felt with carbon cement in order to prevent the fibres from scattering.

Further, the shaped felt as shown in Figure 2 of the accompanying drawings has been proposed. This has a three layer configuration consisting of the three shaped felt parts 3a, 3b and 3c. In this configuration, the

innermost shaped felt part 3a which is heated to the highest temperature is made of a better insulating material with a higher density, while the outermost layer 3c which is not heated to such high temperature is made of a material with a smaller heat capacity and a smaller density. With such the configuration, a combination of better thermal insulation with smaller heat capacity can be achieved.

In order to reduce the heat loss, other methods are also proposed. In one method, a cylindrical container containing inorganic powder such as carbon powder or zirconia powder is used. In another method, a sheet material made of carbon, molybdenum or the like substances which reflect infrared rays is used in order to decrease the heat loss due to thermal radiation.

In principle, the optical fibre or the semiconductor can be efficiently produced when a large amount of raw-materials are treated in the furnace. However, it is not practical to treat a large amount of mass since in the absence of a method for the effective thermal insulation, the furnace requires a larger scale facility and also consumes a larger amount of electrical energy.

It is an object of the present invention to provide efficient thermal insulation to construct a more effective furnace without enlarging the scale of the facility or increasing the amount of consumed electrical energy.

According to the present invention, there is

provided a furnace comprising a cylindrical heater and a cylindrical insulation around the heater, wherein the insulation exhibits anisotropy in heat transfer, and the direction along which the thermal conductivity of the insulation is small corresponds to the direction along which the temperature gradient within the insulation is steep.

The present invention will now be described in greater detail by way of examples with reference to the remaining figures of the accompanying drawings, wherein:-

Figure 3 shows a sectional view of one embodiment of a high temperature furnace;

Figure 4 shows a sectional view of another embodiment of a high temperature furnace; and

Figure 5 shows graphically the results of the test on the thermal insulation of the furnaces.

Within the insulation of the high temperature furnace, the temperature gradient is not uniform, but is gentle or steep in a certain direction. Heat tends to be transferred from a high temperature zone to a low temperature zone along the direction along which the temperature gradient is steep. Therefore, on the thermal insulation, it is most effective to prevent the heat transfer along this direction.

The amount of the heat transferred per unit area of the insulation can be calculated according to the following equation:

$$H = \lambda \times \Delta T$$

wherein H is the amount of the heat transferred per unit area of the insulation, λ is the thermal conductivity of the insulation and ΔT is the temperature gradient within the insulation.

Accordingly, a less amount of the heat is transferred along the direction along which the temperature gradient is gentle (that is, ΔT is small) while a larger amount of the heat is transferred along the direction along which the temperature gradient is steep (that is, ΔT is large).

According to the present invention, a material having anisotropy in the heat transfer is used as the insulation around the heater of the furnace, and the direction along which the thermal conductivity of the

insulation is small corresponds to the direction along which the temperature gradient within the insulation is steep, which results in the effective thermal insulation of the high temperature furnace.

The present invention will be further described with reference to the accompanying drawings.

Figure 3 shows a sectional view of one embodiment of the furnace according to the present invention, in which a plurality of laminates are used as the insulations. The laminate consists of a plurality of graphite sheets which can be also act as the infrared rays reflecting sheets as described above.

In Figure 3, the heater 2 is installed around the muffle tube 1, and the insulation 4 is disposed around the heater 2. The insulation 4 is a composite of cylindrical form as a whole and consists of six insulation parts 4a, 4b, 4c, 4d, 4e and 4f. The insulation part 4b constitutes the innermost cylindrical layer facing to the heater 2, on and under which the annular insulation parts 4c and 4e are disposed, respectively. The insulation part 4a is disposed around the insulation parts 4b, 4c and 4e to constitute the outermost cylindrical layer. The annular insulation parts 4d and 4f are disposed on and under the insulation part 4a, respectively.

The insulation parts 4a to 4f are made of the laminate produced by laminating a plurality of the graphite

sheets 5. These parts are disposed so that the laminating direction of each part is different as shown in Figure 3. The term "laminating direction" is intended to mean the direction of increase in the thickness of the laminate by laminating the sheets. The cylindrical parts 4a and 4b are disposed peripherally and the parts 4c and 4d, and 4e and 4f are disposed axially, respectively relative to the axis of the muffle tube 1. The thermal conductivity of the graphite sheet 5 is smaller along the direction perpendicular to the major surface of the sheet (that is, the direction of the thickness of the sheet). On the contrary, the thermal conductivity along the major surface of the sheet is as large as ten times of such the small thermal conductivity.

In the high temperature furnace comprising the cylindrical heater and the muffle tube, heat generally tends to be transferred along the direction parallel to the muffle tube 1 and across the muffle tube 1. Hence, the temperature gradients along such the two directions are particularly steep within the insulation.

In the furnace with the construction based on the present invention as described above, the graphite sheets 5 are laminated along two directions along which the temperature gradients are steep. Therefore, the thermal conductivities along such the directions are reduced to one tenth in comparison with the directions perpendicular to such two directions. According to the equation (1), then,

the amount of the heat transferred through the insulation 4 is decreased, which leads to the effective insulation.

In the prior art, the directions of the fibres in the carbon felt are random, which results in the isotropic heat transfer in the insulation. This means that along the direction along which the temperature gradient is gentle, the thermal conductivity is small, which can be said to be an excess insulation. Therefore, along this direction, the less insulation will be satisfactory. According to the present invention, the insulation along the direction along which the temperature gradient is gentle is reduced and the insulation along the direction along which the temperature gradient is steep is enhanced, which results in improvement of the total efficiency of the thermal insulation of the high temperature furnace.

<u>Example and Comparative Examples 1 and 2</u>

The furnaces of the present invention and the prior art were tested on the efficiency of the thermal insulation and the results are shown in Figure 5. In Example, the furnace according to the present invention as shown in Figure 3 was tested. In Comparative Examples 1 and 2, the furnaces of the prior art as shown in Figures 2 and 1, respectively, were tested.

In Figure 5, each area A shows the amount of the heat transferred along the direction parallel to the axis of the muffle tube 1, and each area B shows the amount of the

heat transferred along the direction perpendicular to the axis of the muffle tube 1. Such the amounts of the transferred heat were determined from the temperature increase of a cooling water system (not shown) surrounding the furnace.

The temperature of the heater was 2000 °C in each example. The cylindrical insulation of each furnace had an inner diameter of 140 mm, an outer diameter of 350 mm and a length of 300 mm, as a whole. The size of each parts constituting the insulation are shown in following Table 1.

Table 1

	Outer diameter (mm)	Inner diameter (mm)	Length (mm)
Example			
Part 4a	350	250	250
4b	250	140	200
4c	250	140	25
4d	350	140	25
4e	250	140	25
4f	350	140	25
Comparative Example 1			
Part 3a	180	140	300
3b	250	180	300
3c	350	250	300

Each part was made by laminating the graphite sheets having the thickness of 0.7 mm. The insulation of

the furnace in Comparative Example 2 was made of carbon felt which had no anisotropy.

It is clearly understood from the results shown in Figure 5 that in Comparative Example 1 in comparison with Comparative Example 2, the amount of the heat transferred along to the direction perpendicular to the axis of the muffle tube (that is, area B) is reduced by virtue of the insulation of the three layer configuration insulation, but the amount of the heat transferred along the direction parallel to the axis of the muffle tube (that is, area A) increases. As a result, the total amount of the transferred heat is not so changed.

On the contrary, in Example with the use of the furnace according to the present invention, the amounts of the heat transferred, not only along the direction perpendicular to the axis of the muffle tube, but also along the direction parallel to the axis of the muffle tube are reduced by installing the thermally anisotropic insulation parts so that for each part, the direction along which the temperature gradient is steep may correspond to the direction along which the thermal conductivity of the insulation is small. Then, with the use of the present furnace, the amount of the transferred heat is reduced to about 60 % in comparison with Comparative Example 2.

The present invention has been described with the reference to one embodiment of the present furnace

comprising the composite insulation consisting of six parts of the insulation 4, but the present invention is not limited to this embodiment.

For example, it is possible to constitute the composite insulation with more number of the insulation parts. Also, as shown in Figure 4, the graphite sheets 5 may be curved continuously to surround the heater 2, which results in the more effective insulation.

The material constituting the insulation is not limited to a carbon sheet such as the graphite sheet, and the infrared rays reflecting sheet made of molybdenum can be also used. It is preferable to use a sheet or fibrous material in order to make the insulation having the anisotropy in heat transfer. Further, it is also possible to give the anisotropy in heat transfer to the insulation by aligning fibres made of quartz, alumina or zirconia.

As explained with the preferable embodiments of the present invention, it is possible to insulate the high temperature furnace effectively by using, as the insulation, the anisotropic material in heat transfer and having the direction along which the thermal conductivity of the insulation is small correspond to the direction along which the temperature gradient is steep. Thus, on insulating the high temperature furnace which treats a large mass of the material, the problems as to the enlargement in the scale of the facility and the increase in the amount of the consumed electrical energy can be overcome.

CLAIMS:-

1. A furnace comprising a cylindrical heater and a cylindrical insulation around the heater, wherein the insulation exhibits anisotropy in heater transfer and the direction along which the thermal conductivity of the insulation is small corresponds to the direction along which the temperature gradient within the insulation is steep.

2. A furnace according to claim 1, wherein said insulation is provided to exhibit anisotropy by aligning ceramic fibres made from one of the following materials, carbon, quartz and alumina.

3. A furnace according to claim 2, wherein said cylindrical insulation is composite consisting of a plurality of insulation parts made by aligning the fibres along one direction in a respective part and the parts are combined so that the aligning direction of each part is different.

4. A furnace according to claim 1, wherein the insulation is constructed so that a plurality of infrared ray reflecting sheets with small thermal conductivity are laminated along the direction of thickness of the sheet.

5. A furnace constructed substantially as herein described with reference to and as illustrated in Fig. 3 or Fig. 4 of the accompanying drawings.

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